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The contrast law of shadow mask display tubes

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THE CONTRAST LAW OF SHADOW MASK DISPLAY TUBES

SUMMARY

Contrast law (gamma) measurements on typical 19 in. (49 cm) tubes are discussed. The value of gamma obtained depends on factors such as first-anode potential, and whether cathode or grid drive is used. In addition, any failure of regulation of tube supplies, video non-linearity or clamp failure, can affect the overall gamma of pictures from different types of monitor or receiver using a particular tube.

This report describes measurements on typical 19 in. tubes with well regulated supplies and good video linearity, using a range of electrode potentials in order to examine how the gamma may vary with operating conditions. The most probable value of gamma is found to be 2·8; the variation from this value is not likely to exceed ± 0·2.

1. INTRODUCTION

It is well known that the light output of a display tube is related exponentially to the drive potential. An experimental determination of this exponent (usually termed gamma) has been made.

The measurements were restricted to grid drive using a range of first-anode (a_1) potentials. It is known that cathode drive would produce similar results to grid drive with a high a_1 potential, but the equipment available was unsuitable for investigating this.

The necessity for investigation over a range of first-anode (a_1) potentials arises from the various methods of grey-scale tracking which may be used. The monitor in which the tubes were examined is intended to achieve grey-scale tracking with equal video-drive voltages on each of the three grids. Wide ranges of 'slope' (a_1) and 'background' (g_1) voltage adjustments are therefore provided, so that the drive sensitivity and gamma of each gun can be adjusted to a compromise setting for reasonable grey-scale tracking. However, the range of control of drive sensitivity available by this method is not always sufficient to compensate for tube manufacturing tolerances and also the grid/cathode voltages for cut-off almost invariably become unequal.

The range of gain controls on some monitors has recently been extended so that the a_1 potentials may be set as high as possible with equal grid/cathode cut-off voltages on all guns. The three guns then have very similar contrast laws but the drive sensitivities are different; this is then compensated by adjustment of the gain controls to obtain the correct white point.

2. TEST METHOD

The first method of grey-scale tracking was used for the initial measurements, with all guns switched on. The contrast-law characteristics of the individual guns were measured with approximately-equal low grid/cathode cut-off voltages (corresponding to low a_1 potentials) and with approximately-equal high grid/cathode cut-off voltages (corresponding to high a_1 potentials). For the second method of grey-scale tracking the value of gamma obtained with a high grid/cathode cut-off potential would be more appropriate and is closely similar to the value that would be obtained with cathode drive. This method of drive is now gaining popularity in the most recent domestic receivers which have R.G.B. decoding.

During all tests the E.H.T. (25.7.kV), first anode and cathode potentials were continuously monitored.

Each video amplifier linearity was checked and the black-level potential at the grid measured.

The test signal was provided by a patch generator which produced a square patch of adjustable size at the centre of the picture; this was set to 3% of the total picture area, unless otherwise stated. The brightness of the remaining area could be varied so that the effects of flare could also be included in the measurements.

The brightness of the patch was measured by a 'Spectra' spot photometer. The photometer had internal flare so that the readings of the patch brightness became increasingly incorrect as the area surrounding the patch was increased in brightness; this error was removed by placing a black mask over the tube face with an aperture equal to the patch size through which the brightness measurement was made.

3. THE MEASUREMENTS

The following measurements were made:

- (i) The contrast law using a 3% area patch and black surround.
- (ii) The contrast law using a 3% area patch and a surround with 33% of white brightness.
- (iii) The contrast law using the entire picture area.
- (iv) The contrast law of individual guns at different first-anode potentials.

Measurements (i), (ii) and (iii) were made with the white colour temperature set to D6500°K, using the normal slope and background controls provided on the monitor. The patch covered only 3% of the total area for measurements (i) and (ii) so that any inadequacy of supply regulation would have virtually no effect. The signal level was controlled by a precision attenuator.

Measurement (iii) was made to check the performance of this particular monitor under conditions in which the stability of supplies is severely tested.

Measurement (iv) was made to investigate the change in gamma with varying conditions of use of the tube in different monitors.

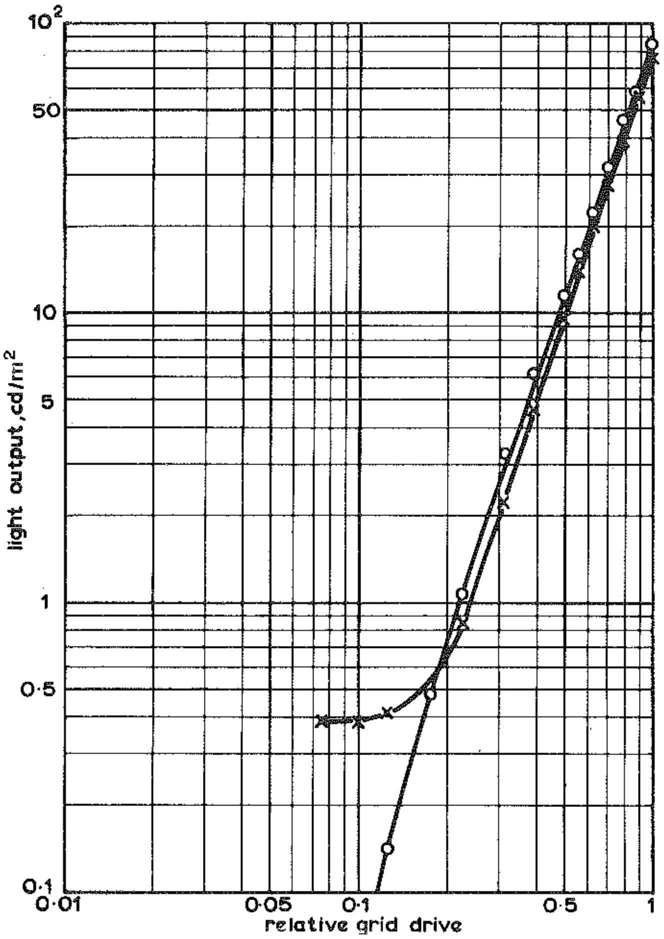

Fig. 1 - Contrast law measured using a 3% area white (D 6500°K) patch

(*a*) —○— Black surround
(*b*) —×— 33% White surround

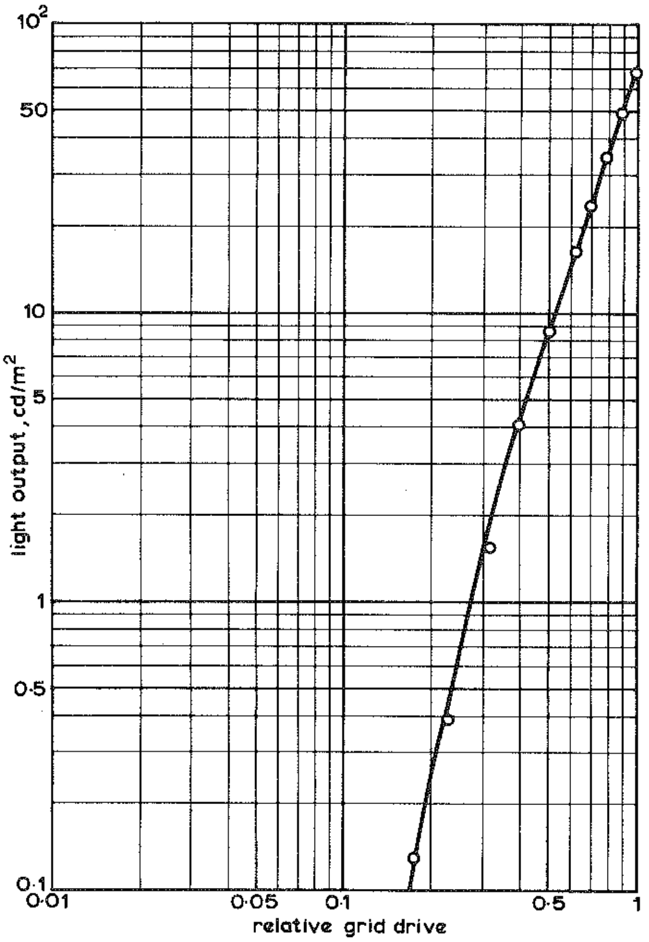

Fig. 2 - Contrast law measured using the entire picture area producing (D 6500°K) light

Detailed measurements will be given for only one tube.

4. EXPERIMENTAL RESULTS

4.1. The Contrast Law using a 3% Area Patch and Black Surround

Light output at peak white = 84 cd/m^2 (24·5 ft L)

Ambient light reflected from screen = 0·002 cd/m^2 (0·0006 ft L)

Cathode potential stability = ± 0·05 V
First-anode potential stability = ± 0·5 V
E.H.T. potential stability = ± 0·1 kV
} short term stability during measurements

Fig. 1, curve (*a*), shows the characteristic relating light output to input voltage, plotted on logarithmic paper. It will be seen that it is not a straight line below a light output of 1 cd/m^2 (0·29 ft L) and therefore not a pure power law over the entire range.

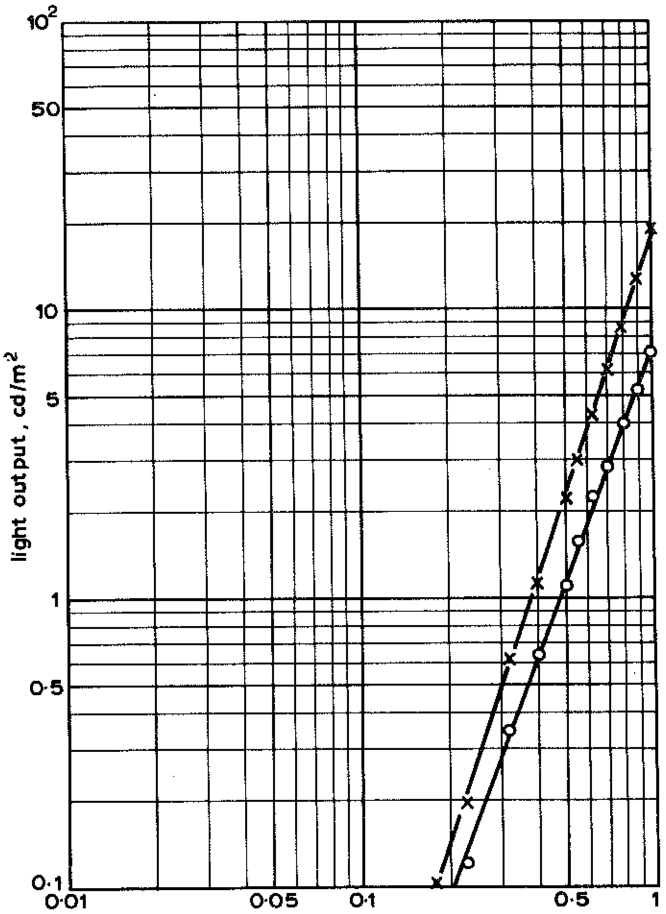

Fig. 3 - Contrast law of red gun only

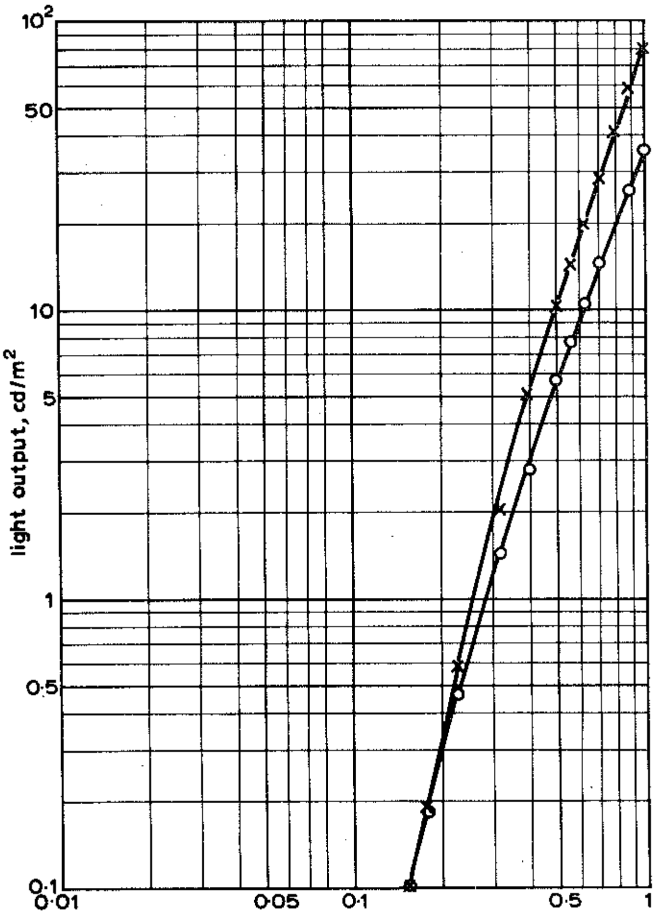

Fig. 4 - Contrast law of green gun only

This is to be expected since the definition and adjustment of tube cut-off is a somewhat indeterminate quantity and initial electron emission velocities also become significant. In this and all subsequent measurements the slope of the curve is taken over the substantially linear portion starting from white, so that errors due to the indeterminate cut-off are minimized. Curve (*a*) in Fig. 1 has been regarded as linear over the light output range between 84 cd/m^2 (24·5 ft L) and 1 cd/m^2 (0·29 ft L); the appropriate value of γ determined from the slope of Fig. 1, curve (*a*), is 2·9.

4.2. The Contrast Law Using a 3% Area Patch and a Surround with 33% of White Brightness

Curve (*b*) in Fig. 1 has been regarded as linear over the light output range between 75·5 cd/m^2 (22 ft L) and 1 cd/m^2 (0·29 ft L); the appropriate value of γ is thus 3·0. The 'displayed contrast' is the ratio of the surround brightness of 25 cd/m^2 (7·3 ft L) to the lower limit of illumination of the patch of 0·39 cd/m^2 (0·11 ft L), or 64 : 1. This corresponds to an extreme condition in which the picture consists of a small black patch in a large white area; the displayed contrast for an average picture will be in excess of 100 : 1.

4.3. The Contrast Law Using the Entire Picture Area

Fig. 2 shows the light output as a function of input voltage. In order to keep the operating conditions within the potential-stability limits specified in Section 4.1 the white output had to be below 69 cd/m^2 (20 ft L), otherwise the beam current limiter in the E.H.T. supply began operating. The curve has been regarded as linear over the light output range from 69 cd/m^2 (20 ft L) to 4 cd/m^2 (1·17 ft L): the appropriate value of γ is 3·0.

4.4. The Contrast Law of Individual Guns at Different First-Anode Potentials

The measurements were all made using the 3% area patch with a black surround. Each gun was measured separately, with the beam from the other two guns cut off. Table 1 shows the values of gamma obtained at the highest and lowest first-anode potentials obtainable. Figs. 3, 4 and 5 show the measurements from which the values of gamma were calculated.

The first-anode (a_1) potentials were measured with respect to cathode. The cut-off potential was measured between grid and cathode, with no signal applied to the grid, when the tube was judged visually to be just at cut-off.

TABLE 1

	Potential (Volts)		Light Output cd/m^2		
Gun	Cut-Off	First Anode	Maximum	Minimum	Gamma
Red	52	145	19·2	0·62	3·0
Red	104	359	6·9	0·62	2·7
Green	61	132	79·0	1·37	3·0
Green	126	336	35·0	1·37	2·7
Blue	62	131	7·6	1·7	3·0
Blue	128	335	3·6	1·7	2·7

The values of gamma are all 3·0 (to two significant figures) for low first-anode potentials and 2·7 for high first-anode potentials.

5. ACCURACY OF MEASUREMENTS

Errors in the measurement of gamma could be caused by failure of regulation of supplies, by incorrect choice of cut-off potential, by ambient light, or by flare. Regulation of supplies was adequately checked and should not have caused any significant inaccuracy.

Incorrect choice of cut-off was likely to have produced the greatest errors; to reduce the effects of this, the slopes of the light-output/relative grid drive curves have been measured only when nearly constant. The cut-off setting accuracy was probably ± 2% of the peak drive voltage. Fig. 6 shows a theoretical contrast law with a slope of 3·0 and the effect of allowing for a ± 2% error in cut-off potential. The slopes of the curves were then measured by joining the point where the light output was 1·0 units to the point where the light output was 0·06 units. A maximum slope of 3·1 and a minimum of 2·8 is obtained so that the corresponding gamma measurement errors due to cut-off setting can be taken as ± 0·15 (to two significant figures).

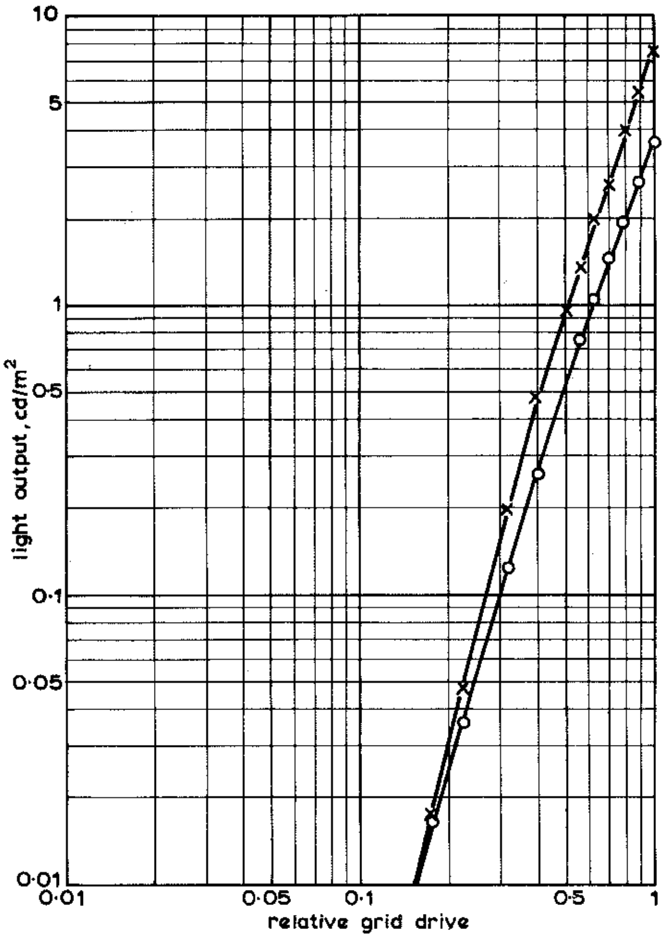

Fig. 5 - Contrast law of blue gun only

—○— (a_1) Maximum

—×— (a_1) Minimum

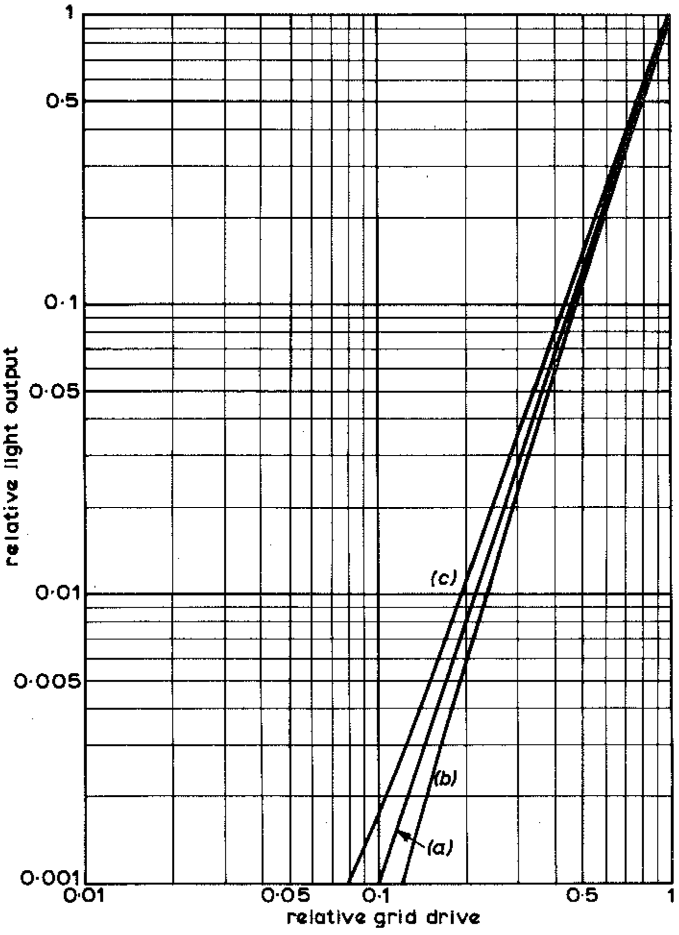

Fig. 6 - Errors of measurement due to incorrect cut-off adjustment

(*a*) Cut-off correct

(*b*) Cut-off error + 2% of peak signal

(*c*) Cut-off error – 2% of peak signal

Ambient light will also produce errors by adding a constant value of light output to that of the display. Measurements were therefore made in a light-tight room with low-reflectance walls.

Flare can cause inaccuracy as shown by the measurements in Section 4.2. Again an error of at least 0·1 in slope is probable if flare is not kept to a minimum by a suitable choice of test signal, and by masking of the tube face to eliminate flare in the spot photometer.

6. DISCUSSION OF RESULTS

A single value of gamma cannot be given, since the operating conditions of tubes vary.

Flare, ambient light and incorrect cut-off all cause the contrast law to depart from a pure power law and cannot therefore be expressed in the form of a modification to the value of gamma. Knowing the value of gamma for the tube itself, curves can be constructed showing the effective contrast law in the presence of any particular value of ambient light reflected from the screen, or for any cut-off setting. The effect of flare is to produce a variation of contrast law depending on picture content.

7. CONCLUSIONS

The value of gamma for a typical shadow-mask display tube can be assumed to be 2·8 ± 0·2. The tolerance is due to the dependence of contrast-law characteristics on certain tube operating potentials, and the practical limitations of measurement accuracy.

JMP

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